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Quantitative Determination of Ablation in Weight of Lumbar Intervertebral Discs With Holmium:YAG Laser

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Background and Objective: **Since 1992, the Ho:YAG 2100 nm laser has been in regular use in percutaneous lumbar disc surgery through the uniportal approach. In vitro experiments were done to find out the exact amount of ablated tissue in weight per energy used with the present beam delivery system.**
Study Design Materials and Methods: **Thirty dissected human lumbar discs were treated with the Ho:YAG laser with 12×10^6 W/cm^2 of effective power density, under 20 ml/min of continous irrigation. The ablation amount was determined through indirect comparison, using the water content of each disc as reference, which was predetermined individually by freeze drying.**
Results: **The ablation of nucleus pulposus is 32.293 mg/kJ in dry weight and 104.719 mg/kJ in physiologic weight. The ablation capacity in annulus fibrosus is ~50% of that in nucleus pulposus.**
Conclusion: **With 20 kJ of energy, the average amount of energy used in actual operations, the mean ablation of nucleus pulposus is 0.556 ± 0.06 (n = 3) grams in dry weight, and 1.89667 ± 0.162 (n = 3) g in physiologic weight.**

Key words: Ho:YAG laser, lumbar disc surgery, percutaneous endoscopic nucleotomy

INTRODUCTION

In 1992, a system of beam delivery via a flexible catheter, which contains laser fiber together with a flexible endoscope system and an irrigation system, was introduced to the percutanuous lumbar disc surgery. Percutanuous lumbar nucleotomy was performed using this catheter (LASE Kit®, Coherent, Palo Alto, CA) and 2,100 nm Ho: YAG laser, under continous saline irrigation. It is important to know the actual amount of tissue removal in the operation. In the literature, ablation is usually described by determination of ablation volume [1–4]. Direct determination of *ablation by weight* by direct weighing of the disc after laser treatment will not be accurate since the changes in fluid composition of the disc are neglected in calculations. The disc tissue swells as it absorbs the irrigation fluid, and at the same time it looses water as heat is developed by applied laser energy. In order to avoid these factors, we have chosen an *indirect method*, in which the water and dry tissue composition of the disc before the laser treatment are first measured and the amount of tissue loss in dry weight after laser treatment is calculated using the pretreatment water–tissue composition as a reference value.

MATERIALS AND METHODS

Human lumbar intervertebral discs from cadavers of 30–70 years of age were used for study. The freshly dissected spine specimens were stored at −27°C. At the beginning of the experiment, they were thawed and the intervertebral discs dissected out. Dissection was done carefully to free each disc of bone, cartilage, and ligament tis-

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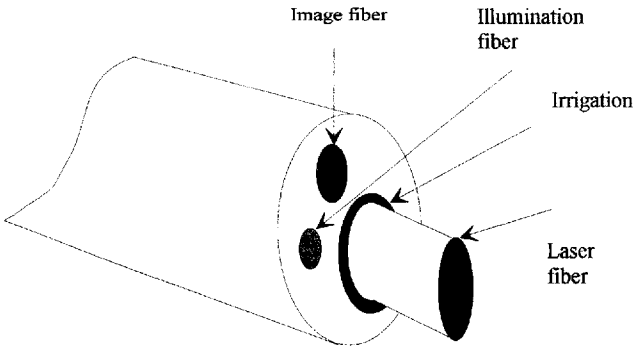

Fig. 1. Schematic drawing of the tip of the uniportal Lase Kit® spinal catheter.

sues, so that inaccuracy in determining water content of disc would not arise from attached tissues.

A pulsed Ho:YAG laser (Versa Pulse® 2.1 Model/3000, Coherent® Medical Group, Palo Alto, CA) of 2,100 nm wave length was used. Enery was set at 1.4 J at a frequency of 10 Hz and an average power of 14.0 W. Energy was transferred to the tissue via a single 320 μ silica glass fiber of 350 cm in length. This fiber is incorporated in a catheter (LASE Kit®) of 1.7 mm in total diameter, especially designed for percutanuous lumbar spine surgery. This catheter system also contains a light source, an image fiber, and an irrigation system (Fig. 1).

Effective power output is measured by using a precision power meter (Labmaster-E®, Coherent) and a highly sensitive energy detector (Newport® Coherent Medical Group in Palo Alto, CA). In this beam delivery system, energy loss along transport is measured to be ~15%. Measurable effective power output at the fiber tip in a 14 W average energy setup is 12 ± 0.5 W. With the laser beam applied without focusing at contact range, the effective power density of this system is then 12×10^6 W cm^{-2} (1220703.125 W cm^{-2}).

At first, each dissected disc was divided sagittally into two equal halves and then the cut halves were weighed. The first half of each intervertebral disc was dried by freeze drying and the tissue water content and dry tissue content in percent were calculated. These were used as reference values for the calculation of ablation weight of the other complementary half of the same disc. The other disc half was treated with laser, in continuous contact mode, under continuous saline irrigation of 20 ml/min. Total energy used varied from 2.5 to 20 kJ. At each energy level, three procedures were performed in 18 disc specimens at nucleus pulposus and in 12 disc specimens at annulus fibrosus. After completion of laser treatment the lased disc half was completely dried by freeze drying to determine the remaining tissue amount in dry weight. The ablated tissue in dry weight was calculated using the following formula:

$$A_d = II_w \times \frac{I_d}{I_w} - II_{dl}$$

A_d = tissue ablation in dry weight
I_d and I_w = dry weight and wet weight of the first disc half
II_w = wet weight of the second disc half
II_{dl} = dry weight of the second disc half after laser treatment.

The working assumption, that the two complementary halves of the same disc have approximately equal tissue-water composition, was supported by separate experiments that showed the difference in water content between the halves to be 0.953 ± 0.122% (n = 4).

RESULTS

The mean water content of examined lumbar intervertebral discs is 69.07019 ± 2.759% (n = 30). Water content varies from 62.3% to 73.62%. The majority (80%) of the discs contains water between 66 to 72%.

Eighteen discs were lased in the nucleus pulposus with a total of 180 kilojoules of energy in three separate series of experiments. The results in dry weight are shown in Figure 2. The ablation in natural weight or wet weight can be calculated using the water content of that particular disc as reference (Fig. 3). The average amount of ablated pulposus tissue per kilojoule of laser energy is 32.293 mg in dry weight and 104.719 mg in wet weight.

Twelve discs were treated in the annulus fibrosus with total energy of 150 kJ in three series of experiments. The ablation amount in annulus fibrosus is ~50% of that in nucleus pulposus (Fig. 4).

DISCUSSION

The aim of the percutaneous lumbar nucleotomy is the decompression of the disc and evacuation of the bulge of disc herniation by partial removal of nucleus pulposus avoiding segmental

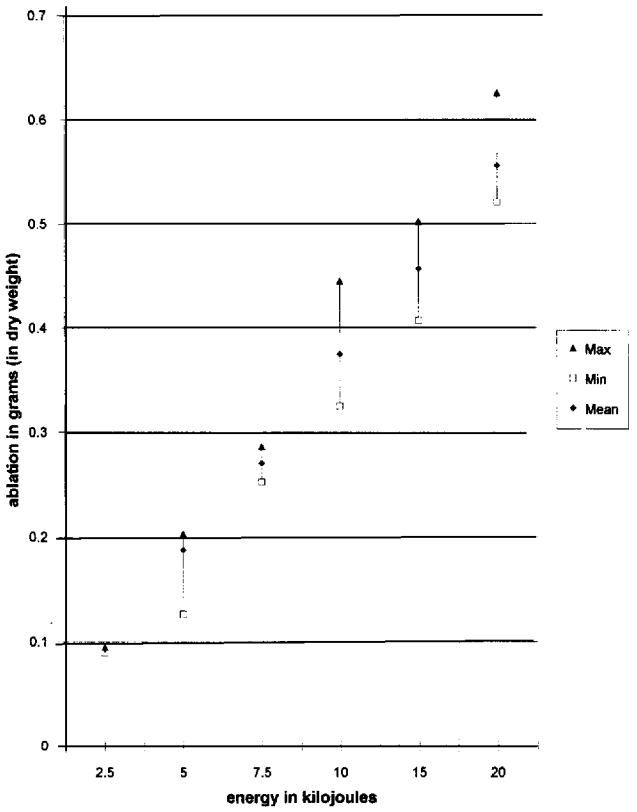

Fig. 2. Amount of ablation of pulposus tissue in dry weight (n = 3 for each data point).

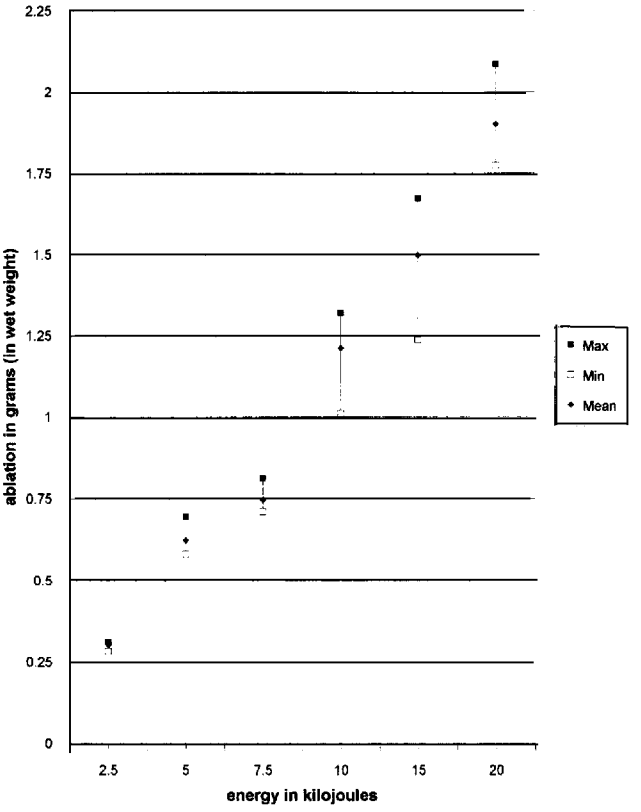

Fig. 3. Amount of ablation of pulposus tissue in natural (wet) weight (n = 3 for each data point).

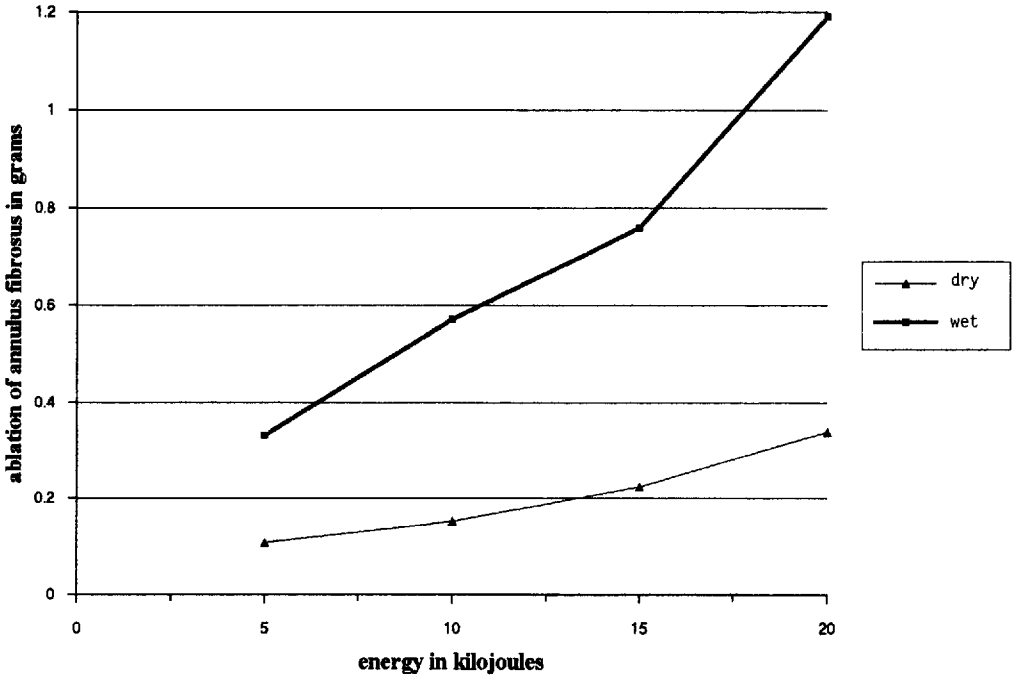

Fig. 4. The mean amount of ablation of annulus tissue in wet weight (above) and dry weight (below) (n = 3 for each data point).

instability [5]. Although it is difficult to find direct a correlation between the amount of disc tissue extraction and the clinical result, the ideal goal always has been to achieve the best results with least possible amount of tissue extraction, as large amounts of disc tissue removal clearly predisposes to segmental instability. Only a few authors reported the amount of removed disc tissue during percutaneous lumbar disc hernia operations with mechanical means. Tissue removal ranged from 1–4 g [6–8] up to 18 g [9], and all authors reported good results at the time of study.

Since the introduction of lasers into percutaneous nucleotomy, various preliminary clinical experiences were published [10–13], but the ablated tissue amount was never determined. With our in vitro experiments, we describe a precise quantitative determination of tissue ablation under the conditions as close as possible to those during the actual operations. We have been doing percutaneous lumbar discectomy with this uniportal flexible catheter endoscopic system since 1992 in selected patients, using 20 kJ of energy on average per operation. The results after 12 months follow-up were good without any neurological complications [14]. The mean amount of tissue removal with 20 kJ is shown to be 1.89667 g of nucleus pulposus in its physiological weight.

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